CEM3394 uP CONTROLLABLE SYNTHESIZER VOICE

DESCRIPTION

The CEM3394 is a complete analog music synthesizer voice-on-a-chip intended for software control by a microprocessor system. Included inside the compact 20 pin package is fully temperature compensated, wide range, voltage controlled oscillator providing triangle, sawtooth, and pulse waveforms; a voltage controlled mixer for adjusting the balance between the internally generated VCO waveforms and any external signal; a dedicated four-pole low-pass voltage controlled filter with voltage controlled resonance; a modulation amount VCA for modulating the filter frequency by the triangle waveform output of the VCO; and a final VCA for allowing the output to be enveloped. Envelope control for both the VCF and final VCA may be provided by either a hardware envelope generator such as the CEM3310, CEM3371, or through software.

Ranging between -4 and +4 volts, all eight control inputs are provided with internal very high input impedance, low bias current buffers. Thus interface to a microprocessor system may be accomplished simply with a single DAC, 4051-type CMOS multiplexer, and 8 hold capacitors.

Requiring a bare minimum of other external components, the CEM3394 is ideal for low cost polyphonic or polytimbric musical instruments featuring rich, analog sound.

FEATURES

- Low Cost
- Complete synthesizer Voice on a Chip
- 20 Pin DIP Package
- Sample & Hold buffers on-chip for easy interface to a uP
- Fully temperature compensated VCO
- Independently selectable VCO waveforms
- Constant Loudness vs Resonance VCF
- Rich Sounding VCF Design
- Filter FM routing for more Timbres
- Low Noise, Low Feedthrough VCA
- Few External Components

CEM3394 Electrical Specifications

PARAMETER	MIN	TYPICAL	MAX	UNITS
VCO Specifications				
Frequency Range	12Hz	---	20KHz	
CV Input Range	-4.0	---	+4.0	Volts
CV Scale Factor	-0.65	-0.75	-0.85	V/Octave
Exponential Error (<8KHz)	---	0.3	1.0	%
Temperature Coefficient	-500	0	+500	ppm
Reference Voltage (pin 1-3)	1.10	1.20	1.30	V
CV Input Current	---	0.3	3.0	nA
Frequency at CVin = 0.0V	330	500	750	Hz
WAVE SHAPER				
Waveform Select Thresholds				
Triangle	-0.20	-0.35	-0.5	V
Triangle + Sawtooth	0.90	1.20	1.50	V
Sawtooth	2.30	3.00	3.90	V
Wave Select Input Current	---	-50	-300	nA
Pulsewidth CV for 0% Pulse	0	---	0.2	V
Pulsewidth for 100% Pulse	1.9	---	2.2	V
FILTER MODULATOR				
Max Modulation Depth	0.01X	---	2.0X	Freq.
CV for 0% Modulation	-0.3	---	0.1	V
CV for Max Modulation	3.0	---	4.0	V
CV Input Current	---	-0.5	-5.0	nA
FILTER INPUT MIXER				
External Input Level	---	80	---	mV @ 5% THD
External Input to Output Gain	3.6	4.5	5.6	mmho
CV Input Current	---	-0.3	-3.0	nA
External Input Bias Current	---	-0.3	-0.7	uA
CV Feedthrough	-30	0	30	uA
4-POLE LOW-PASS FILTER				
CV Input Range	-3.0	---	+4.0	V
CV Scale Factor	-0.33	-0.38	-0.43	V/Octave
Frequency @ CV = 0.0V	900	1300	1800	Hz
Frequency CV Input Current	---	-0.3	-3.0	nA
Resonance CV : No Resonance	0	---	0.3	V
Resonance CV: Oscillation	2.0	2.5	3.0	V

CEM3394 Electrical Specifications (cont)

PARAMETER	MIN	TYPICAL	MAX	UNITS
FINAL VCA				
Attenuation at CV = 0	80	90	---	dB
CV for Maximum Output	3.8	4.0	4.3	V
CV Scale Factor (20-100dB)	---	20	---	dB/V
Triangle Wave Output Level	190	250	325	uA pp
Triangle + Sawtooth Output	255	330	430	uA pp
Sawtooth Output Level	150	200	260	uA pp
Square Wave Output Level	120	160	210	uA pp
All Waves On Output Level	300	400	520	uA pp
CV Feedthrough	---	+-0.3	+-3.0	uA
CV Input Current	---	0.3	3.0	nA
POWER SUPPLIES				
Positive Supply Range	+4.75	---	+8.0	V
Negative Supply Range	-4.75	---	-16.0	V
Positive Supply Current	13	16	21	mA
Negative Supply Current	-13	-16	-21	mA

APPLICATION HINTS

POWER SUPPLY

The CEM3394 was designed to operate from +5V and -6.5V supplies. The non-standard negative supply was necessary not to compromise the VCO frequency resolution, which ranges from -4 to +4 volts, in favor of a -5V supply (*this is because there needs to be 4 diode drops for the current mirrors…ed).* Any one of the readily available 3-terminal regulators (LM337, for example) may be used to supply the -6.5V negative supply. Since the stability and jitter of the VCO are directly affected by noise on the positive supply, a supply as stable and clean as possible should be use *(not the +5V digital supply…ed.)* Maximum supply allowable across the device is 25 volts.

VCO

The control scale of the VCO is temperature compensated with an internal +3300ppm tempco generator and multiplier. Thus, as chip temperature changes, the control voltage applied to the exponential generator changes proportional to temperature, effectively canceling the -3300ppm tempco of the control scale.

The resistor Rz from Pin 1 to the negative supply sets up an internal reference current for the exponential voltage-to-current converter. Its value and that of timing capacitor Ct determine the nominal initial frequency of the VCO at zero CV applied. The equation is:

Fout = (Vref)/(Vcc x Rz x Ct)

where Vref is the voltage across pins 1 and 3, nominally 1.3 volts. The other consideration is the current range of the V to I converter, which is optimized for a range of 300nA to 80uA. Using 80uA as an upper limit, the timing capacitor is chosen by:

Ct = (80uA)/(Fmax1 x Vcc)

where Fmax1 is the maximum frequency at the best accuracy (80uA).

In a typical application, suppose the best accuracy is in the range of 32Hz to 8KHz. Thus Fmax1 is 8KHz, and Ct is calculated to be 2nF. The middle of this range is 500Hz which is set to Fout. Therefore Rt calculates to 260K. Note that since the VCO input range is -4 to +4 volts with a scale factor of 0.75 V/Octave, the VCO will sweep from 12Hz to 20KHz.

A -5V negative supply can be used if the sweep range is reduced. In this case, Ct = 4nF and Rt = 65K.

Since the VCO was designed to be software adjusted, a simple multiplier was used with slight non-linearity at its two extremes. Therefore, for best results, it is recommended that the scale factor and scale linearity be auto-corrected through software means.

WAVEFORM SELECTION

The pulse width may be turned off simply by setting the Pulse Width control voltage slightly negative to ensure a pulse width of 0%. A unique circuit on-chip keeps the average DC level of the pulse waveform constant regardless of duty cycle, so that pulse width may be modulated without annoying control signal feedthrough.

The relative amplitudes of the three waveforms have been set as follows to give approximately equal loudness: The triangle is 27% larger than the sawtooth, which is about 27% larger than the pulse wave.

EXTERNAL INPUT

The external input may accommodate any signal up to about 80mV pp; normally, a resister divider is required to attenuated the input signal to this level. The resistance to ground should be 1k to keep the VCA balanced, and the input signal should be capacitively coupled to minimize control voltage feedthrough. A small adjustable offset of +-20mV may be applied to this input to further reduce CV feedthrough.

The internal signal and external signal are nominally in equal balance- each being 6dB down from its maximum, when the control voltage is at zero volts. The control scale is roughly audio taper: the first 20dB of range is linear while the remaining 60dB is exponential. This external input is ideal for adding noise, a second VCO, or both.

VCF

Able to sweep over a minimum of 14 octaves, the filter is the classical wide range 4-pole low-pass type designed for musical instruments.

The control scale has twice the sensitivity as that for the VCO: it is 3/8V per octave. The first 3 stages of the filter are unity gain transconductors while the last stage provides a gain of 57 (and consequently has a transconductance of 1/57 of the first three). This requires three equal capacitor values, and the fourth is $1/57^{th}$ of the other value.

The frequency of the -12dB point on the cut-off slope is given by:

Pzcv = Gm/(2 x pi x Ceq) = (Iref)/(4 x pi x Ceq x VT)

where VT = KT/q = 26mV at 20 C. The reference current is set up internally an given a +3300 ppm to compensate for the VT -3300ppm tempco. Thus this equation can be reduced to:

Pzcv = 4.3 x 10E-5/Ceq

Note that due to internal resistor tolerances, the 4.3E-5 term can vary 40% part-to-part.

Selection of the 4 filter capacitors is again determined by the maximum desired cut-off frequency and optimum operating range of the OTAs. The range has been optimized for an operating range of 5 umho to 5 mmho. Thus we can calculate C as follows:

C = 5E-3/(2 x pi x Fmax)

As an example, assume the highest cut-off frequency is 24Khz. C1-C3 becomes 33nF and C4 is (33nF/57) = 580pF. The frequency at zero control volts is approximately 1300Hz; 24Khz will be reached in 4.2 octaves, or at -1.6V. The filter can be opened up to >40Khz using these values, but CV feedthrough becomes excessive.

The resonance VCA feedback circuit has been designed so that as the resonance is increased the apparent loudness remains constant, providing a much richer resonant sound. Note, however, that the peak-to-peak level of a pule/square wave actually doubles as resonance is increased, due to the ringing on its fast edge transitions.

VCF MODULATION

The modulation VCA allows the VCO triangle wave to modulate the reference current of the VCF, and hence the cut-off frequency. The Modulation Amount control voltage (Pin 5) controls the ‘depth’: at maximum setting the VCF is swept from a very low value to twice the unmodulated frequency. Since the modulation is linear, the apparent filter frequency does not shift as modulation is increased.

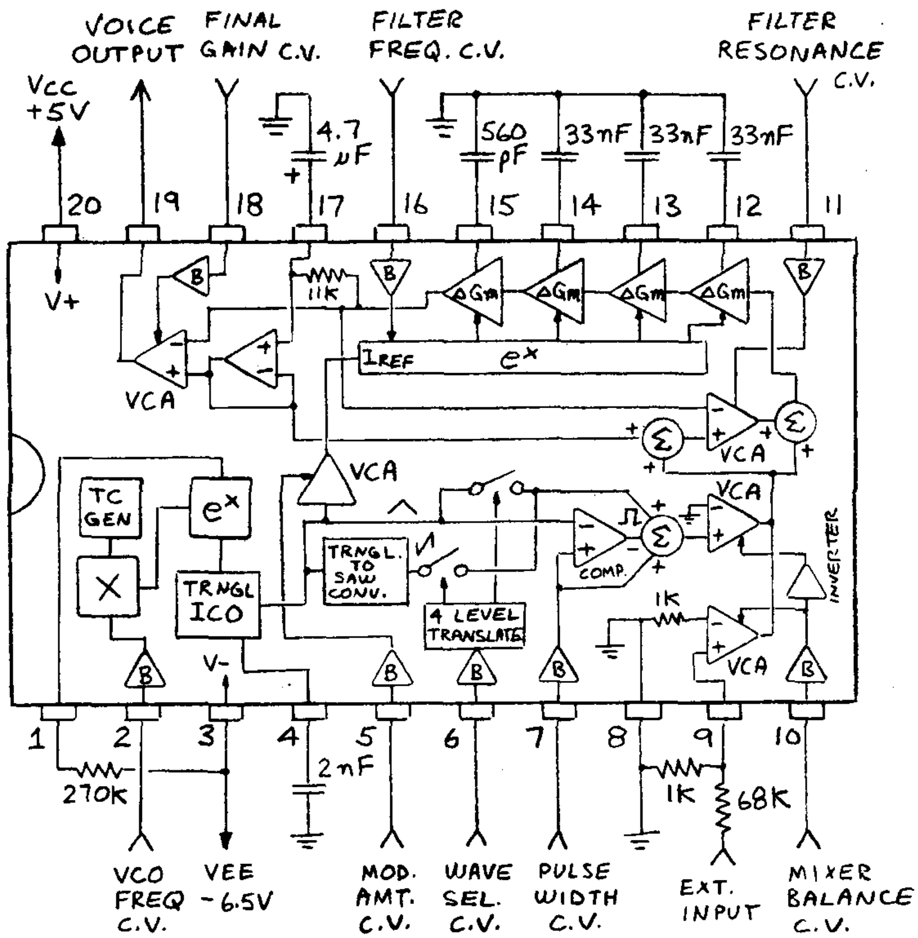
One application of this control is to set the filter into oscillation for obtaining linear audio FM of one VCO by another (using the VCF as a VCO). However, an equally interesting application is to audio FM the filter while it is filtering normally. The result is strong timbral effects, especially with some resonance added.

FINAL VCA

The final VCA is a low noise, low control feedthrough design which substantially reduces fast envelope click and pop noises without the need for a trimmer. The output of the filter is essentially AC coupled to the VCA input by means of the bypass capacitor connected to Pin 17. Thus, its value along with the internal 11K resistor sets the low corner frequency; a value of 4.7uF results in a -3dB point of 3Hz. This pin may also be used to extract the filter output signal before it is passed through the VCA.

The final VCA control scale is approximately audio taper. The first 20dB of attenuation from a control voltage of +4V to +2.5V is linear. The next 60 to 80dB of attenuation is from +2.5V to 0V is exponential. This allows the natural sound of exponential decays to be produced with simple linear envelope control, which is much simpler to generate in software.

The signal output at Pin 19 is a current with a voltage compliance of Vee+1 to Vcc-1. This allows the outputs of multiple 3394s to be mixed together by connecting all Pin 19s together. The summed current can then be converted to a voltage simply by a resistor to ground, or an op-amp with feedback resistor. The major portion of the 40% tolerance on the maximum output swing (nominally +-210uA) is due to the monolithic diffused resistors setting the currents. Although the output variations part-to-part are typically much less than this *(about 5-10%, ed.)* , output levels as well as the filter initial frequency may be more closely matched by matching the resistance between the Vcc and Vee pins.



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BLOCK AND EXTERNAL CONNECTIONS DIAGRAM